NASA Implementation Plan

For The

National Space Transportation Policy

November 7, 1994

(Revised)

Table of Contents

National Space Transportation Policy
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Background

This plan is submitted in response to Presidential Decision Directive/NSTC-4 entitled National Space Transportation Policy issued on August 5, 1994. The policy provides guidance for space transportation activities and plans of the civil, military, intelligence, and commercial space sectors.

Overall, the policy calls for a balanced, two-track effort; first, to ensure continued access to space by supporting and improving our existing space launch capabilities, consisting of the Space Shuttle and current Expendable Launch Vehicles (ELV's); second, to pursue the goal of reliable and affordable access to space through focused investments in, and orderly decisions on, technology development and demonstration for next-generation reusable transportation systems.

NASA has been assigned responsibility for the next-generation reusable technology development/demonstration program, leading to a decision by the President, no later than December 1996, on proceeding with a subscale flight demonstration which would prove the concept of Single-Stage-To-Orbit (SSTO). The objective of the program is to support Government and private-sector decisions by the end of this decade on development of a full-scale operational next-generation reusable launch system.

It is envisioned that the private sector could have a significant role in managing the development and operation of a new reusable space transportation system. In anticipation of this role, NASA shall actively involve the private sector in planning and evaluating its launch technology activities.

The policy also provides that NASA will maintain the Space Shuttle system until a replacement is available, using the Space Shuttle for missions that require human presence, to exploit its unique capabilities, or for national security, foreign policy, or other compelling purposes.

NASA will also support the Department of Defense (DOD) in its lead agency role for the improvement and evolution of the current expendable launch vehicle fleet.

This plan responds to NSTC-4 and provides a NASA implementation plan in the following three areas: The Reusable Launch Vehicle (RLV) Program, Space Shuttle, and ELV's. The RLV Program, as used in this paper, encompasses the technology maturation and flight demonstration activities that will lead to a next-generation reusable launch system.

Emphasis

During 1993, in response to congressional direction, NASA conducted an Access to Space study which examined three possible approaches to continued assured access to space. The study concluded that the most beneficial option would be to develop and deploy a fully reusable, pure-rocket launch system, incorporating advanced technologies. The study determined that, while the goal of achieving fully reusable rocket launch vehicles has existed for a long time, recent advances in technology make such a vehicle practical in the near term, provided that necessary technologies are matured and demonstrated prior to the start of vehicle development.

Within this context, industry and NASA are embarking on a path to develop and demonstrate new technologies for the next generation of reusable space transportation systems that can radically reduce the cost of access to space. Involvement by the Government, at industry's request, will be in areas where the Government's technical expertise and assets can be used to their fullest advantage.

The Government-industry partnership concept is further reinforced by the use of joint Government-industry synergy teams that participate in the selection of the key technologies and in the design of the test programs and evaluation criteria for validating the technology. Thus, the decisions relating to the acceptability of components for the demonstrators and other reusable vehicles will be predicated on a mutual Government and industry understanding of the maturity and applicability of specific components.

I. Reusable Launch Vehicle (RLV) Technology/ Demonstration Program

1.0 RLV Implementation Plan Purpose and Scope

The NASA RLV Implementation Plan defines the program goals and technical objectives. It also covers the NASA management plan, including technology development, schedule, funding, coordination, and procurement approach. NASA will execute the RLV program in cooperation with the Departments of Defense, Commerce, and Transportation, and in consultation with the Director of Central Intelligence. The details of DOD's role are defined in the DOD Implementation Plan. The Departments of Commerce and Transportation plans, to encourage private-sector participation, are defined in their joint plan.

2.0 RLV Program Goals and Objectives

The goal of the RLV program is to move immediately to mature the technologies essential for a decision on a next-generation reusable launch system capable of reliably serving the U.S. Government's and the commercial space transportation needs at substantially reduced costs. The anticipated lower flight costs of the next-generation system will permit U.S. industry to regain a competitive global position as a provider of commercial space launch services. Substantially lower flight costs will act as a catalyst in the development of space-based commercial, industrial, and research activities.

The primary objectives of the RLV program are to (1) mature the technologies required for the next-generation system, (2) demonstrate the capability to achieve low development and operational cost, and rapid launch turnaround times, and (3) reduce technical risk to encourage private investment in the commercial development and operation of the next-generation system.

2.1 Implementation Strategy

The RLV program is an integrated, fast-track approach for reducing the technical and business risk in developing economical, operational, reusable launch vehicles. An integrated ground and flight test program is being implemented to characterize key component technologies and to validate their systems' capabilities, both from a performance and operations viewpoint.

To commit to specific component technologies for both the flight demonstrators and the full-scale operational vehicle, it is necessary to demonstrate that components have robust and well-understood design margins relative to the applications for which they are intended. Thus, the ground test program will entail cycling of the candidate components under realistic environmental conditions to establish the acceptable number of flight cycles before deterioration, or failure of the components will occur. Each of the technology components will incorporate sensors that will permit detection of incipient failure.

The flight test demonstration program will be implemented to identify component and system integration issues in the RLV program that are unresolved by ground test and to confirm the environments that are employed in the ground tests. The demonstration program consists of a series of flight vehicles, each of which will move Government and industry toward the level of confidence necessary for a decision for full-scale vehicle development by the end of the decade. In addition to validating the technology in an integrated system with realistic operations, maintenance, and flight environments, the program also provides a platform for developing and expanding the Government-industry partnership and provides practical experience in routine operations of reusable systems.

Immediately upon approval of this implementation plan, NASA will release a Cooperative Agreement Notice (CAN) that will result in the fastest possible delivery of an X-33 Advanced Technology Demonstrator (ATD). NASA is prepared to expedite awards 90 days after approval of this plan. For the X-33, NASA plans to make multiple Phase 1 awards for the concept design and intends down-select the ATD(s) by July 1996 for construction and flight as early as possible but before July 1999. NASA will make every effort to accelerate this schedule and will assist the selected contractor(s) in any feasible manner to fly the ATD(s) before July 1999.

Also immediately upon approval of the plan, NASA will release a CAN for expedited delivery of an X-34 Small Booster Technology Testbed. This will be a joint industry/government funded program to develop a small reusable booster to demonstrate materials and operations technologies. The program will be also used as a test bed for validating new and innovative ways of doing business. The Small Booster will enable the U.S. commercial space sector to more competitively meet future launch needs in the light payload class.

In addition to the flight demonstrator vehicles, the Space Shuttle may be used as a testbed for appropriate new technologies and components. In many instances, this aspect of the program has the promise of being highly synergistic with the Space Shuttle improvement and maintenance program.

3.0 RLV Program

The RLV program will consist of developing and validating vehicle, propulsion, and operations technologies. These technologies will be progressively integrated and flight-demonstrated on three experimental test vehicles, the DC-XA, X-34 and X-33. The integrated program is shown on Figure 1 -- RLV Implementation Plan. While the program will be aggressively expedited, dates shown should be regarded as nominal with some adjustments to be expected as the program advances. Details of the overall program are provided in the following sections.

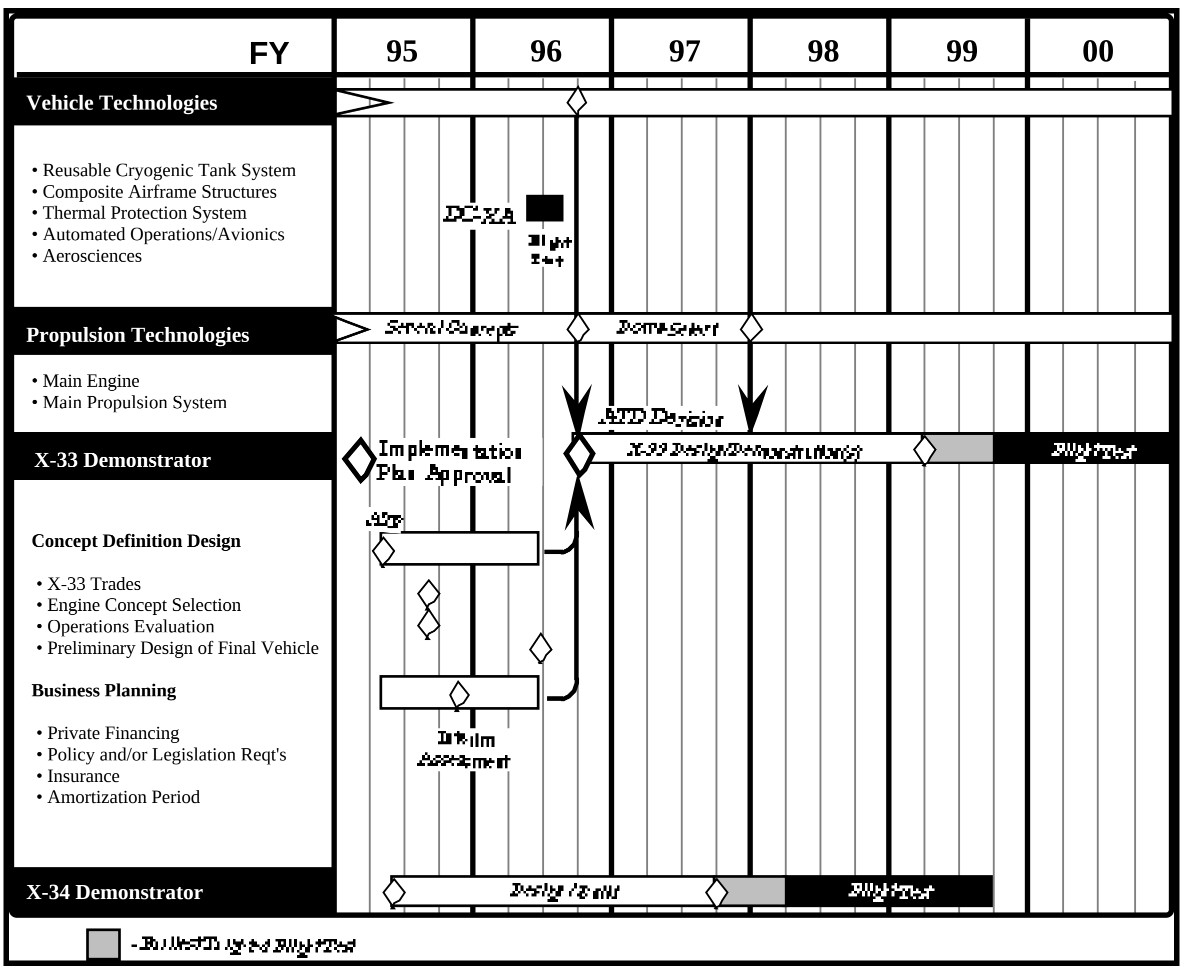

Figure 1.-- RLV Implementation Plan

3.1 Concept Definition

Concept definition and design activities for the flight vehicle and technology demonstrators will identify the enabling technology requirements. This process will evaluate the merits of vehicle concepts for a given set of mission and system requirements with a focus on reduced operations costs. The three basic vehicle single-stage rocket configurations to be evaluated include, but are not limited to, vertical takeoff/vertical landing, vertical takeoff/horizontal landing-wing body, and vertical takeoff/horizontal landing-lifting body.

3.2 Propulsion Technologies

Propulsion technology efforts will demonstrate the operational and performance characteristics of candidate engine and main propulsion systems and define and establish a set of derived requirements for an operable propulsion system. Key targets for the next-generation propulsion system are robustness, operability, high thrust-to-weight ratio, and an affordable development program with acceptable risk. Both U.S. and foreign technologies that offer the potential for expediting the development of technology for future next-generation engines will be investigated. Ground-based subscale engine and main propulsion systems demonstrations will provide a testbed for demonstration of operability and performance targets and will permit extrapolation of targets from demonstrated conditions to full scale. A technology component development activity will validate design concepts, define component hardware response, and demonstrate cost-effective manufacturing processes.

Candidate engine systems currently identified for reusable vehicles include both bipropellant (e.g., LO_2/LH_2) and tripropellant (e.g., LO_2/LH_2/RP-1) engines. Initial studies indicate that tripropellant or advanced bipropellant (high thrust-to-weight configurations) propulsion systems are required to achieve sufficient design margins. Engine concepts being evaluated include a Space Shuttle Main Engine (SSME)-derived dual bell, an advanced aerospike, an advanced full-flow-staged combustion cycle single bell for bipropellant, an SSME-derived bell-annular concept, an RD-704-derived concept, and an RD-0120-derived concept for tripropellant. Key technologies for all of these concepts include LO_2 rich compatible materials, modular combustion chamber development, and the use of advanced Ceramic Matrix Composite (CMC) materials in component designs.

3.3 Vehicle Structural Technologies

Vehicle structural technologies encompass reusable cryogenic tank systems, graphite-composite structures, and Thermal Protection Systems (TPS). The efforts focus on the operability and integration of the load-carrying airframe structure, cryogenic insulation (as required), thermal protection material, and associated health management for the next-generation system. Early (1994-96) activities will be a balance of laboratory experiments, ground testing, and flight testing to establish the operability, performance, and limits of candidate solutions. Foreign technologies that offer the potential for expediting the development of advanced technology for future structural systems will be investigated. Later efforts (1996-99) will focus on the development of large-scale hardware for flight testing on the X-33.

The reusable rocket must return from orbit with its cryogenic propellant tanks, presenting complex thermal-structural challenges. Issues associated with life-cycle effects on the integrated tank system—tank wall, cryogenic insulation, and TPS—must be addressed. Aluminum-lithium (alloys) and graphite-composite tank materials are being considered. To significantly reduce structural mass and alleviate fatigue and corrosion concerns, nonpressurized airframe structures will be constructed of graphite composite, drawing on current aircraft and rocket designs. These include both low- and high-temperature composites. TPS candidates for acreage areas include both ceramic and metallic concepts. Leading edge, nose cone, and control-surface material candidates include advanced carbon/carbon and CMC.

3.4 Operations Technologies

To meet the fundamental goal of affordable access to space, a major emphasis will be placed on realizing significant savings in operations cost through advancement in operations and maintenance technologies and processes. Fast turnaround times, small ground crews, and airline-type maintenance will permit operations costs to drop dramatically.

Automated operations technologies will be applied to the streamlining and simplifying of the ground and flight operations of the next-generation system to achieve cost and performance goals. Technologies include automated checkout, vehicle health management/monitoring systems, autonomous flight controls and "smart" avionics/guidance navigation. Incorporation of process enhancements such as one-time flight certification, hazardous materials elimination, ground-scheduling systems, and a philosophy of reliability-centered maintenance and minimum operations between flights will contribute to an aircraft-like operations process. A detailed reliability, maintainability, and supportability approach will be established and executed throughout the program to ensure that the vehicle can indeed be operated in an efficient and cost-effective manner.

3.5 Flight Demonstrations

As an integrated system, flight demonstrations force the key technology development and operations issues to surface, thus minimizing technical and operational risk during the more costly next-generation-system development phase. These are also the key testbeds for proof-of-system operability and rapid turnaround times. The following paragraphs describe the planned demonstrators and their respective roles in the development and demonstration of RLV technologies.

3.5.1 Delta Clipper - Experimental Advanced (DC-XA)

The Delta Clipper-Experimental (DC-X) vehicle, developed and initially demonstrated by the Ballistic Missile Defense Organization, will be transferred to NASA, and advanced technology upgrades will be installed, reconfiguring it as the DC-XA. The following technology components are currently planned to be incorporated into the vehicle: (1) aluminum-lithium liquid oxygen tank, (2) composite liquid hydrogen tank, (3) composite intertank structure, (4) integrated auxiliary propulsion system consisting of a liquid-to-gas conversion system, (5) modified auxiliary power unit, and (6) hydrogen leak-detection sensors. Each of these components will be built to technical specifications traceable and scalable to a next-generation system and will undergo ground-checkout testing prior to installation in the DC-XA vehicle for mid-1996 flight testing. Testing of the upgraded technology components in flight and natural environments will be used to demonstrate system operability.

3.5.2 Small Booster Technology Demonstrator (X-34)

The X-34 will be used to investigate technologies that may be incorporated into future reusable launch vehicles. This program, which will be jointly funded with the commercial launch industry, minimizes development uncertainties and accelerates timetables for validating less costly, more operable and reliable small booster vehicle components and flight test articles.

The X-34 will benefit the overall RLV program since it offers the prospect of an early testbed, including a realistic flight environment, for some of the advanced components that could be used for the next-generation system. These components and systems potentially include the following:

- Advanced thermal protection systems (high-temperature nose cap and leading edges),
- Advanced avionics and flight-control systems, including autonomous reentry and landing,
- Vehicle health monitoring systems, and
- Ground operations/rapid turnaround.

Just as important as the technology that it will demonstrate, the X-34 provides an early opportunity to demonstrate streamlined management and procurement, industry cost sharing and lead management, and the economics of reusability. The X-34 is a logical precursor to a full-scale next-generation reusable launch system.

3.5.3 Advanced Technology Demonstrator (X-33)

The X-33 system must prove the concept of a reusable next-generation system by demonstrating key technology, operations, and reliability requirements in an integrated flight vehicle. Critical characteristics of SSTO systems, such as the structural/thermal concept, aircraft-like operations and maintenance concepts, flight dynamics, flight loads, ascent and entry environments, mass fraction, fabrication methods, etc., will be incorporated into the X-33 system. As a minimum, the X-33 will be an autonomous, suborbital, experimental, single-stage rocket flight vehicle.

The Concept Definition/Design Phase, combined with ongoing technology developments and demonstration, will culminate in the selection of the X-33 concept(s) in FY 1996. Business and operations planning results from this phase, when combined with the design maturity and technology status, will serve as major elements in the selection process.

In the first phase, a wide range of technology candidates will be demonstrated to a level of maturity sufficient to reduce the number of alternatives, enabling the design and development of a cost-effective, large-scale technology demonstrator. Sufficient data must be available by the summer of 1996 to support the outyear funding decision.

In the second phase, and based on a Presidential decision to proceed, the X-33 will serve as the flight testbed for large-scale elements of critical RLV technologies and is the focus of the program leading to the next-generation-system decision by the President by the end of this decade. The decision could result in an operational vehicle in the 2005 timeframe. However, depending on the success of the technology development program, the initial next-generation- system operations date could be sooner. Figure 1 provides an overview of key program elements and currently targeted milestones.

4.0 Procurement Strategy

NASA's approach of forging partnerships with industry will be reflected in the use of contractual vehicles, such as cooperative agreements for this joint Government/industry ventures approach. NASA recently extended its policy on cooperative agreements to allow, for the first time, "for-profit" firms to propose and to include Independent Research and Development as part of their corporate contribution.

The X-34 Small Booster Technology program, which NASA proposes to jointly fund with the commercial launch industry, offers an early opportunity to test RLV components and flight operations strategies, NASA intends to issue a cooperative agreement solicitation for development of this booster in the first quarter of FY 1995 and expects to be under contract by the second quarter of FY 1995. Flight tests are targeted to begin in the fourth quarter of FY 1997.

The current plan is to initiate the X-33 system planning effort in FY 1995 utilizing a Cooperative Agreement Notice for competitive solicitation of multiple, parallel-concept definition studies. The concept definition phase would include definition of linkages between the X-33 and laboratory-based demonstrations and would propose the approach to the commercial development and operation of a full-scale reusable vehicle after the turn of the century.

To fully understand the development risks and costs of a full-scale launch system, NASA will investigate the viability of employing a "fly-off" approach for development and flight test of multiple X-33 vehicles. Flexibility will be maintained in the program to permit Government and industry to accelerate the next-generation-launch-system decision date.

5.0 Program Management and Coordination

The NASA RLV program is being accomplished in cooperation with the DOD and by involving the private sector in planning and evaluating the activities. The management approach provides a full understanding of the cost, schedule, and development risks before decisions to proceed are made.

Government-industry partnerships and relationships are strengthened by the Aeronautics and Astronautics Coordination Board; the involvement of industry launch providers and users, DOD, and NASA Centers through the Space Transportation Steering Group; and by the involvement of industry, DOD, and NASA in the synergy teams for propulsion, vehicle structural systems, and operations technology. They are illustrated in figure 2.

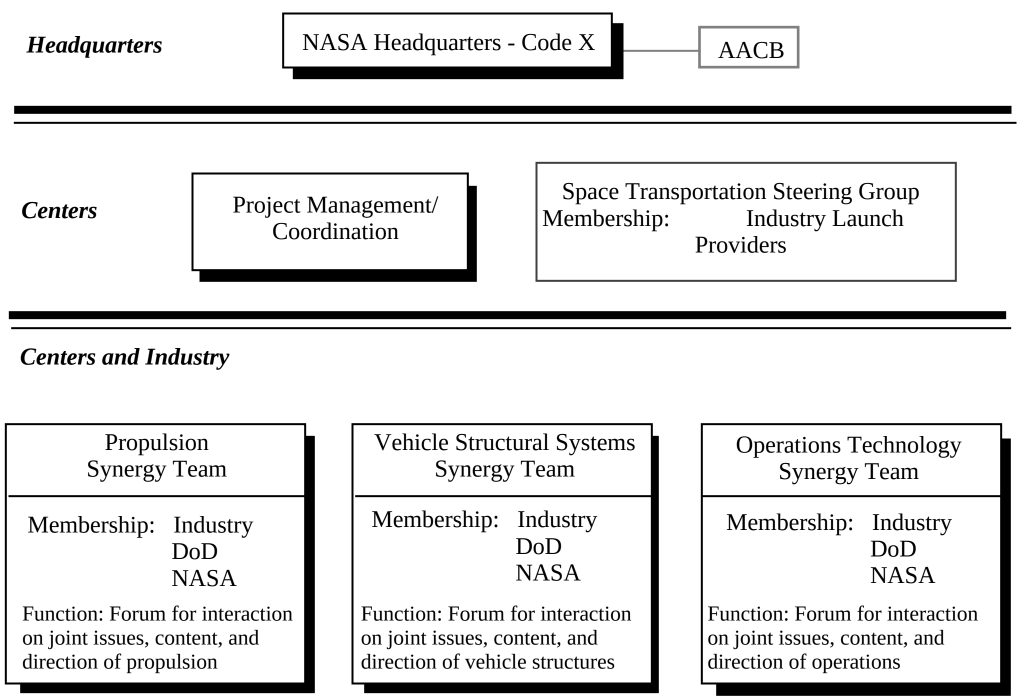

Figure 2.-- Government-Industry Relationships.

Marshall Space Flight Center (MSFC) will serve as the host Center for the program, which will draw upon the resources of other NASA Centers and the U.S. Air Force (USAF) to support the effort. The RLV program will be managed by a small program office, as shown in Figure 3. Government and contractor personnel will be minimized in order to demonstrate the effective streamlined management approach necessary to reduce development and operations costs. This approach will incorporate the experience gained from the DC-X program.

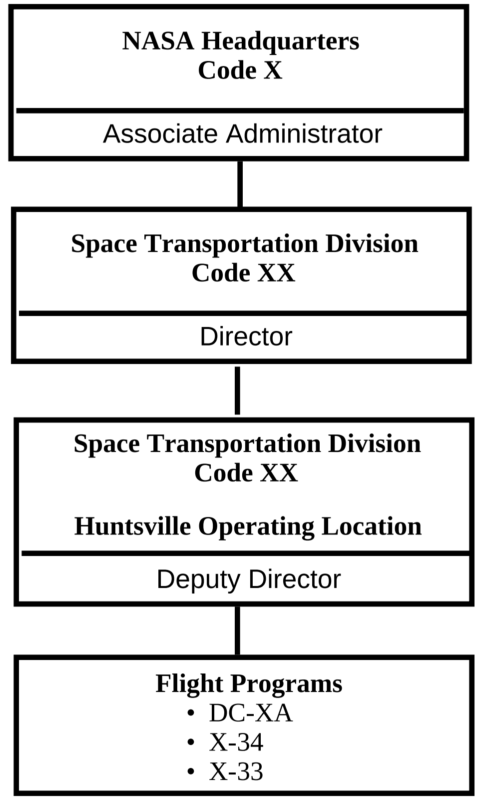

Figure 3.-- RLV Program Organization

The USAF has been designated as the DOD organization which will coordinate and manage related DOD investments, including RLV and ELV technologies. The cooperative NASA/USAF technology program will provide the technology base for future related applications of both agencies. The USAF, with its expertise in aircraft operations, maintenance, and flight testing, will bring these complementary disciplines to the cooperative RLV activities. With these capabilities, the USAF will provide leadership in the RLV flight demonstration program for operations concepts, performing flight-test range facilitation, flight-test planning, and flight-test operations.

The DC-X program, which preceded this effort, was executed by DOD by the aggressive application of similar management concepts and principles. NASA intends to adapt its internal procedures and its relationship with industry and DOD and apply these concepts and principles to the RLV program.

The new model for the relationship among NASA, industry, and DOD is a partnership. The concept of a partnership embodies mutual responsibility for the effort, mutual benefit from the research and design efforts, and mutual contribution of assets to the execution of the effort. The ownership, benefits, and contributions of the partners need not be equal but must be negotiated and well understood by all parties. Once begun, the relationship can evolve, adapting to the results of the effort and changing external requirements.

6.0 RLV Decision Criteria

In keeping with NASA's focus on measuring what we manage, criteria by which the progress of the RLV is measured will be developed by NASA in coordination with OSTP and OMB.

By December 31, 1994, NASA will propose technical and programmatic criteria to provide the basis for the 1996 and full scale development decisions on whether to proceed with the next phase of the program.

The process for both NASA internal and external reviews, to define the criteria and to assess program progress leading to recommendations by the NASA Administrator and subsequent approval to proceed, will be consistent with the decision dates specified in the National Space Transportation Policy (NSTC-4).

7.0 Program Funding

During FY 1994, NASA obligated $34 million on RLV- related technology. For FY 1995, NASA is planning to obligate $94 million for the RLV program. The budget was derived from the detailed plans for the baseline technology program developed by the NASA Centers and reported in the Access to Space Study Report, January 1994. In addition, Congress has appropriated a total of $65 million for use in DOD support of the RLV program. It should be noted that the budget allocations assume that the technical efforts be conducted through partnerships established via cooperative agreements with industry. The program budget will be updated annually to reflect actual versus planned expenditures and also to document revisions to the technical or resources plans as a result of specific accomplishments, challenges, and opportunities that develop as the program progresses.

The President's 1996 budget plan contains full funding through FY 1997 for the DC-XA and X-34 flight demonstrators, for X-33 concept definition, and for the technology program. The FY 1996 and outyear budgets also contain additional X-33 and technology funds, the release of which is contingent on Administration approval in 1996 to proceed with the X-33 demonstrator. Administration approval is anticipated upon satisfaction of the RLV decision criteria.

II. Space Shuttle

1.0 Introduction

The Space Shuttle Implementation Plan includes the programmatic approach, rationale, schedules, and funding required to implement the Space Shuttle portion of the National Space Transportation Policy, Presidential Decision Directive/NSTC-4. In accordance with the policy statement, NASA's Space Shuttle implementation plan meets all the criteria specified in the introduction with particular emphasis on the following elements:

- Balancing efforts to sustain and modernize existing space transportation capabilities with the need to invest in the development of improved future capabilities,
- Maintaining a strong space transportation capability and technology base,
- Promoting the reduction of the cost of current space transportation systems while improving reliability, operability, responsiveness, and safety, and
- Fostering technology development and demonstration that will support future decisions on the development of next-generation reusable space transportation systems that greatly reduce the cost of access to space.

2.0A Common Technology Partnership

The RLV and the Space Shuttle programs will be aligned to create a common technology partnership that serves the Agency well in positioning itself to ensure reliable and affordable access to space. Although RLV funds will not be used for Shuttle unique upgrades, the technology advances required to develop the next-generation system could be applicable to the Shuttle. After demonstration of an appropriate component technology, NASA may apply the technology to the Shuttle. Specific benefits of this partnership to the Shuttle program include reduced operational and ground processing costs, increased system safety and reliability, increased payload capability, and improved probability for launching the Shuttle on time.

Specific RLV technologies that can be validated on the Space Shuttle include the thermal protection system, reusable bipropellant cryogenic engine, vehicle health management, avionics, composite surfaces and structural components, streamlined operations and ground processing enhancements, an integrated cryogenic propellant tankage system and advanced software maintenance. Using the Shuttle as an RLV testbed also provides a clear avenue to address real-world integration issues and focuses efforts to reduce operations costs at both the Johnson Space Center (JSC) and the Kennedy Space Center (KSC). In addition, it offers a unique national asset for large-scale reentry testing.

There are, of course, elements that are unique to each of the programs. Shuttle-unique enhancements could include improved power systems for extended- duration orbiter capability, solid propellant gas generators, and solid rocket motor improvements. Technologies unique to the RLV program include the reusable tripropellant engine and fully autonomous rendezvous and docking system.

3.0Implementation Plan

NASA's Space Shuttle Implementation Plan is a phased approach which pivots on the end of the decade, next-generation-system decision point. The crucial first phase of the plan is the period between now and the year 2000. NASA's integrated Shuttle/RLV approach ensures that it is poised to move forward on either of two scenarios in the year 2000: 1) completing the transition from the Shuttle to a replacement next-generation system by or before 2012, or 2) continuing to operate the Shuttle beyond 2012 (See figure 4). The projected lifetime of the Space Shuttle will depend on the emergence of requirements significantly beyond the Space Station's current life expectancy of 2012.

With the alignment of the Shuttle and RLV programs, most of the expenditures and activities associated with initial RLV development could be pertinent to the future Space Shuttle developments required for either scenario. Most of the expenditures and activities associated with maintaining and improving the Shuttle will have poised NASA to aggressively pursue having a replacement vehicle flying by 2012. What follows is a high-level description of those specific activities planned for the initial implementation phase and the two scenarios.

A Presidential decision not to commit to the next-generation launch system will trigger the need for a concurrent decision at the end of the decade on the future of the Space Shuttle. Depending on the Shuttle life expectancy, NASA may need to embark on a substantial upgrade program, including possible fleet augmentation, to maintain the safety and reliability of the Space Shuttle while reducing its operating costs.

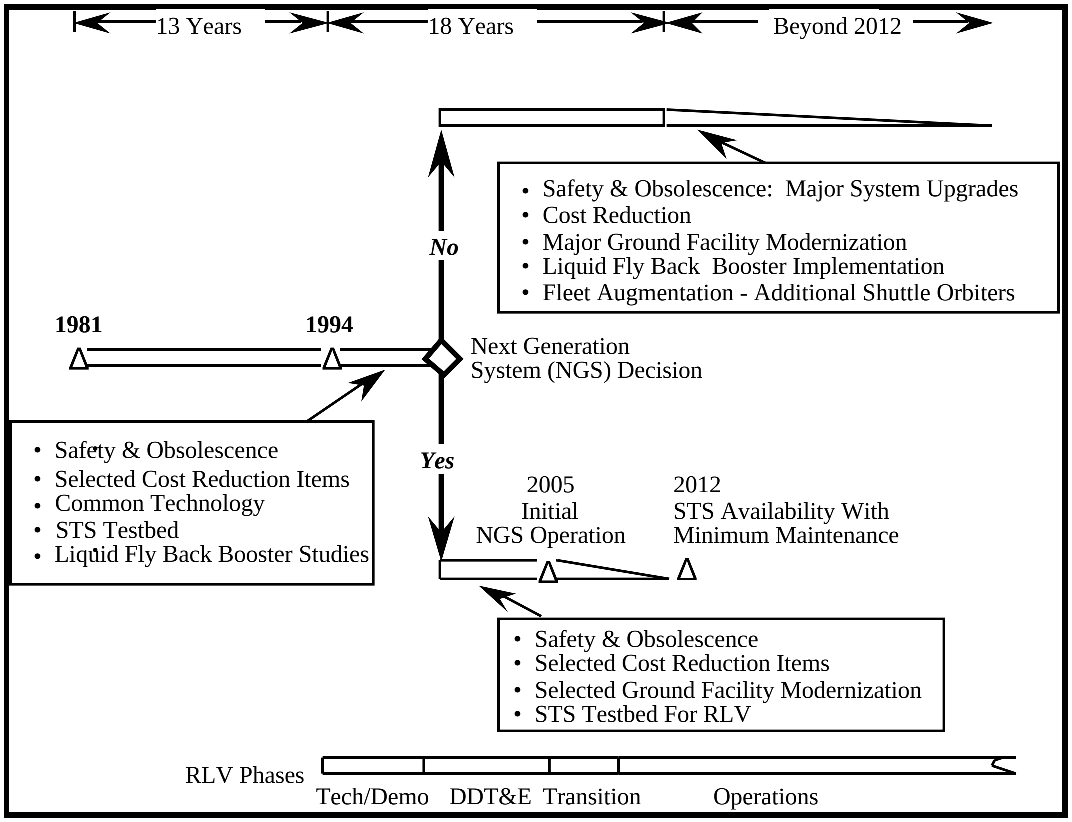

Figure 4.-- Shuttle Phasing Strategy Timeline

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The activities planned in the first phase of the implementation plan are those critical to positioning NASA to move forward on either of the two longer term scenarios. As such, the focus during this timeframe will be on the following:

- Implementing system improvements. An example is the development and implementation of the long-life fuel cells with single-cell voltage checking. The new fuel cell will provide a five-fold increase in life. The instrumentation and longer life will result in reduced removal and replacement and logistics costs with a payback within 2 years. Other improvements include TPS operability improvements, Global Positioning System implementation, fiber-optic payload bay data management, the reaction control system's primary thrusters, and continuation of SSME Block II improvements.

- Mitigating obsolescence issues. Many of the avionics components are 13-year-old designs. These components will face obsolescence issues if flown for another 18 years. Some of these components are the various data recorders, the air data transducer assemblies, Ku-Band logistic replacement units, mass memory units, and television capabilities (upgrade to High-Definition Television).

- Developing the technologies common to the Space Shuttle and RLV program. Many systems benefit from technology insertion to enable new cost-reducing improvements and to enhance the safety of the system. For example, the Space Shuttle has demonstrated the effectiveness of the existing orbiter TPS. However, several material improvements have been identified that have the potential to significantly reduce the orbiter TPS processing costs. Tile damage from debris and rain can be reduced by utilizing a thicker, tougher densification coating known as Toughened Unipiece Fibrous Insulation (TUFI). When applied to advanced tile substrates, such as Alumina Enhanced Thermal Barrier (AETB), a stronger more durable tile is produced. Other technology needs that enable future Shuttle improvements that are in line with RLV needs are advanced ceramic matrix composites, high-temperature waterproofing, vehicle health management, high-power density fuel cells, advanced avionics, and a freon replacement.

- Initiating early technology development efforts on those candidate enhancements to fly the Space Shuttle beyond 2012. Development of hydrazine Auxiliary Power Unit (APU) replacements for the orbiter APU and the Solid Rocket Booster (SRB) APU could provide significant cost paybacks and improve overall system safety. During this time period, advanced development of an electric APU for orbiter and a solid propellant gas generator for the SRB could take place. Initial Phase A studies and selected hardware demonstrations for the Liquid Flyback Booster (LFBB) would posture the program for an early 2000 start.

3.2 2000 to 2012

In this scenario, the Space Shuttle is replaced with the new vehicle by the year 2012. Several activities, however, are still critical to ensure that the Shuttle system flies safely, reliably, and at a lower cost until the replacement vehicle is operational. As such, activities during this time could include the following:

- Continuing implementation of system improvements, including limited application of TUFI/AETB tiles, SSME improvements, SRB improvements.

- Mitigating obsolescence continues for many components for both the orbiter and the SRB's, ground support equipment and facilities at KSC and JSC. Potential obsolescence issues that may occur during this time period are reinforced carbon/carbon tile replacement, inertial measurement unit upgrade, and new general-purpose computers.

- Providing flight test capability for the RLV technologies, including TPS materials and coatings, advanced avionics, and vehicle health management concepts and hardware (ground and flight).

No orbiter fleet augmentation is currently foreseen as required for this scenario. The four- orbiter fleet is expected to absorb the contingency grounding of one orbiter and continue to support six flights per year.

3.3Beyond 2012

If the decision is made to fly the Space Shuttle significantly beyond 2012, major block upgrades will be considered in the year 2000 in addition to continuing to implement system improvements and obsolescence mitigation. The major improvements could include the application of advanced CMC's for TPS operability improvements, rudder speedbrake and body flap, extensive use of TUFI/AETB tiles and full footprint strain isolation pads, an advanced cockpit/avionics suite, increased use of vehicle health management to reduce ground operations costs, replacement of hydrazine APU's with electric APU's, use of electro-mechanical actuators, SSME Block III controller, SSME nozzle improvements, and a new injector.

This longer term Space Shuttle operational scenario could also significantly benefit from the introduction of LFBB's rockets to replace the SRB's. The LFBB's would provide major safety benefits, increased payload performance, increased launch probability, and would reduce the annual SRB operating costs. The SRB's could be replaced with LFBB's between 2007 and 2010.

Production of another orbiter may be needed to ensure long-term availability of the Space Shuttle beyond 2012. Safety and obsolescence and new improvements identified in the technology development partnership between RLV and Shuttle could be incorporated in a new orbiter. Existing orbiters would be upgraded during the orbiter maintenance down periods. A fifth orbiter would be developed between 2002 and 2006, if required. When it becomes operational, one of the older orbiters could be mothballed as a spare for contingency use only. Any decisions on orbiter replacements would be dependent upon attrition or changes in requirements.

4.0 Budget Requirements

The current Space Shuttle program baseline plan includes funding for high-priority safety and obsolescence items until the year 2000. Some activities (engine health monitoring, ground processing improvements, etc.) will be of benefit to both Shuttle and RLV. Candidates for common technology development beyond those currently in the plan would require additional funding (e.g., advanced TPS development and demonstration and advanced development and testing of new vehicle health management concepts).

A beyond 2012 decision could require significant new investments in Shuttle upgrades. A replacement orbiter would cost approximately $3 billion spread over 6 years. A decision to develop LFBB's would require approximately $7 billion over 10 years. Other upgrades (including SRB improvements if LFBB's are excluded) would cost approximately $2.5 billion between 2000 and 2010. These projects would result in significant cost savings to the program if its life extends significantly beyond 2012.

5.0 Summary

The Space Shuttle Implementation Plan, in response to the National Space Transportation Policy, is a phased approach that is aimed at continued improvements in Shuttle operations while making effective use of the technologies emerging from the RLV program. Technology needs common to both programs have been identified, and the Shuttle and RLV implementation plans have been coordinated to obtain maximum leverage from the commonality. The Shuttle implementation approach has been phased to support the RLV decision by the end of the decade and to support either decision scenario after that point.

III. Expendable Launch Vehicles

1.0 Definition of the NASA Role

DOD has been assigned as the lead agency for the technology development for the medium and heavy-lift vehicles, and requirement for NASA's participation in this area will be identified by DOD. The skills and resources available at NASA may constitute a cost-effective approach to support the evolution of these vehicles, and NASA will place its capabilities at the disposal of the DOD within the limits of funding priorities. Consistent with the Launch Services Purchase Act and the new National Space Transportation Policy, NASA will continue to acquire launch services from the U.S. commercial expendable launch vehicle industry to support civil Government launch service requirements.

NASA, in conjunction with the DOD, will develop a memorandum of agreement on the process for combining their expendable launch service requirements into a single procurement when such procurements would result in cost savings or are otherwise advantageous to the Government. Often NASA launch services require special mission-enabling modifications (e.g., vehicle-fairing extension). In coordination with DOD, NASA will continue to be responsible for implementing such changes necessary to meet its mission-unique requirements.

In both the small vehicle class and the larger than Titan IV vehicle class, NASA, in coordination with DOD, will invest in technology as required to develop and evolve these vehicles. In addition, NASA will continuously monitor the RLV program "generic" technologies that would be applicable for expendable vehicles, as well as reusable vehicles, and will coordinate with the DOD regarding the progress on these programs.

NASA currently plans to launch all payloads on space launch vehicles manufactured in the United States, unless exempted by the President or his designated representative. This policy does not apply to the use of foreign launch vehicles on a no-exchange-of-funds basis to support the flight of scientific instruments on foreign spacecraft, international science programs or other cooperative government-to-government programs. Such use will be subject to interagency coordination procedures.

2.0 Representative Near-Term Technology Programs

During 1994, NASA's advanced space transportation activity has been in transition from a "balanced" ELV/RLV program toward a predominant emphasis on reusable technology in recognition of the evolving National Space Transportation Policy of assigning technology leadership for the RLV program to NASA. In 1994, approximately half the transportation technology budget was for reusable vehicles and the remainder was for ELV's or common technologies. In 1995, the allocation for reusable vehicles and for common technologies is in excess of 90 percent of the total transportation technology budget.

Representative technology activities during 1994 in ELV's include a significant hybrid motor test and evaluation program, a sustained solid propulsion integrity program, a series of software developments to improve the operations efficiency of vehicles, demonstrations of electromechanical actuators, and demonstrations of efficient manufacturing processes for aluminum-lithium vehicle tankage.

In the propulsion area, a series of foreign-developed engines are being evaluated for applicability to both the expendable launch and reusable vehicles. In addition, two technology programs for low-cost turbomachinery and LOX-rich combustion (both U.S. and Russian approaches) are being pursued.

A laser-initiated pyro system is also being demonstrated on a sounding rocket and is also planned for demonstration on the Pegasus.

3.0 Long-Term Technical Approach

With NASA assigned as lead agency for the RLV program, the resources available for expendable vehicle technology are limited. However, elements of the technology maturation being accomplished for the reusable vehicle may well have direct applicability for the expendable fleet as well. For example, propulsion components, structural materials, avionics, and tankage may have common applicability to both ELV's and RLV's.

NASA and DOD will work cooperatively to avoid overlap in these technology areas and will provide forums for ensuring that both agencies stay current, regarding the progress being achieved in the individual technology areas. NASA will continue to provide the institutional support, resources permitting, requested by the ELV industry.

Both Langley and Ames Research Centers will continue to support the ELV community in the areas of aerodynamics and aerothermodynamics with the computational fluid dynamics codes that they have developed and with their test facilities. Goddard Space Flight Center will continue to support the industry in the areas of structural, thermal, and trajectory analysis.

NASA intends to continue to invest in the Solid Propulsion Integrity Program at MSFC; however, the program is being modified to foster industry leadership and to include a significant amount of industry funding. MSFC is also managing the hybrid rocket motor Technical Reinvestment Program for the Advanced Research Projects Agency and continues institutional support of the ELV industry, including the areas of acoustic modeling, materials characterization, propellant circulation and conditioning, and design studies.

In coordination with DOD, NASA will continue to support industry initiatives where the use of NASA facilities and resources can minimize the cost and enhance the value of the technology efforts. For example, NASA's Lewis Research Center (LeRC) has been in a technical advisory capacity to the USAF for the Atlas upgrade program. Because of the long association of LeRC with the Atlas vehicle, the Center is able to efficiently bring their experienced personnel and analytic capabilities to the support of the USAF. Finally, NASA will support the DOD when requested by DOD in the evolution and improvement of the existing medium and heavy-lift expendable fleet.

4.0 Procurement Strategy

The NASA ELV technology program will be highly selective in its projects. Because of the limited funds available to invest in this program, it will be confined to those projects which will most benefit NASA and which are of sufficient interest to industry to warrant a cooperatively funded (joint Government/industry) approach. Where mission-unique modifications are required of the existing medium/heavy-lift vehicles, these modifications will be coordinated with DOD and will be accommodated within the NASA procurement contract or the DOD procurement contract for the specific launch service. DOD will be kept informed of all such efforts to potentially maximize the utility of the modification for all U.S. Government missions.

NASA's budget contains funding to continue to acquire launch services from the U.S. commercial ELV industry to support civil government launch service requirements. Consistent with the policy, NASA's budget contains no funds for acquisition of foreign ELVs.